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Using expert knowledge to propose recreational marine reef-fish management measures in Chile

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Abstract

Marine recreational fisheries often lack necessary information to perform assessments and develop sustainable management strategies. In Chile, although reef-fish fisheries have been signaled as overexploited, there are still no commercial or recreational regulations regarding bans, catch limits, or size

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limits. We implemented an expert elicitation protocol to propose management measures to regulate recreational reef-fish harvests of 17 reef-fish species. Sixteen experts estimated minimum legal sizes, temporal closures, and maximum number of individuals harvested per person per trip (known as "bag limits"). Experts also prioritized management measures for each of 17 reef-fish species. Maximum number of individuals harvested per person per trip varied between 1 and 7. In addition, permanent bans were recommended for some species, such as acha (*Medialuna ancietae*), pejeperro (*Semicossyphus darwini*), and San Pedro (*Oplegnathus insignis*). We concluded that information gathered through expert elicitation can play a key role to inform data-poor recreational fishery management. Expert elicitation protocols that include iterative process, based on individual estimates and an open expert discussion phase, provide the necessary enabling environment to identify a variety of management measures. While future challenges include the development of mechanisms to promote acceptability and compliance for recreational fisheries management, the approach presented here is important to initiate much needed discussions.

KEYWORDS

angling, bag limits, bans, data-poor fisheries, IDEA, management reform, recreational fisheries, size limits

1 | INTRODUCTION

Globally, reef-fish fisheries are facing multiple threats, including climate change impacts, unsustainable small-scale recreational extraction, and commercial overfishing (Coleman et al., 2004; Cooke & Cowx, 2004; Hyder et al., 2017; Rummer & Munday, 2017). Several efforts have been placed in assessing the ecological effects that fisheries have had on composition and biomass of reef-fish assemblages (Godoy et al., 2010) and marine ecosystems (Gelcich et al., 2012). However, analyses have generally ignored the role of recreational fishing on marine reef-fish assemblages (Arlinghaus et al., 2019; Freire et al., 2020; Radford et al., 2018). This is unfortunate, as in many coastal countries, unregulated recreational fisheries can play an important role in contributing to the overexploitation of reef-fish (Godoy et al., 2016; Lewin et al., 2019). In addition, in reef-fish fisheries it can be difficult to differentiate between recreational, subsistence, and small-scale fishers (Bower et al., 2017, 2020; Cooke et al., 2017; Freire et al., 2020; Pita et al., 2017). Users can fish for personal gratification while also selling their catch to contribute to their income (Holder et al., 2020; Potts et al., 2019). In some locations, recreational fishers can operate as de facto commercial fishers using recreational licenses (Godoy et al., 2016). The variety of users and interests can become especially challenging to foster sustainability of coastal species when recreational fisheries governance and regulations are weak (Potts et al., 2019).

A global review of recreational fisheries governance highlighted that these fisheries are not considered to be effectively managed in many countries (Potts et al., 2019). This can be critical in countries where clear definitions are lacking in policies and in which regulations are totally absent (Hyder et al., 2020; Potts et al., 2019). In fact, in many developing and middle-income countries, there is still very little information and great uncertainty on the importance and variety of harvested reef-fish species (FAO, 2012). The diffuseness and mobility of recreational fishers within a country also create a huge challenge for the monitoring of catch, defining stock status and establishing regulations (Holder et al., 2020). Marine recreational fisheries often have a low capacity for assessment and management (Hyder et al., 2017, 2020). Therefore, a key challenge is to determine and enforce management measures, ensuring reef-fish sustainability. This requires recreational fisheries management to be tailored toward specific regional conditions and species.

In countries where recreational fisheries data are lacking for decision making, expert and local knowledge can play a critical role to support management (Diogo et al., 2017; Holder et al., 2020). For example, in recreational fisheries, local ecological knowledge has been used to assess the stock status and determine research priorities for data-poor fisheries (Gervasi et al., 2022), experts

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from more than 20 countries have evaluated the potential of using angler smartphones app to inform management (Skov et al., 2021), and angler knowledge has also been used to evaluate status and decline of South Florida bonefish (Kroloff et al., 2019). These experiences are part of a wider body of literature that shows the key role of experts in recommending policies for sustainability and resource management (Estévez et al., 2019; Sutherland & Burgman, 2015). In this line, structured expert methodologies have been proposed to engage experts, reducing biases and errors in their estimates and judgments (Burgman, 2016; Hanea et al., 2021). This approach could help to identify management recommendations in recreational fisheries.

Chile provides an opportunity to study the complexities of recreational fisheries management for reef-fish. Reef-fish fisheries have been signaled as overexploited and there are still no commercial or recreational regulations regarding bans, catch limits, gear restrictions, or size limits (Araya et al., 2015, 2018; Godoy et al., 2016; Pérez-Matus & Cea, 2022). In Chile, recreational reef-fish fishing is usually performed through spearfishing in the central north of the country, with some fishing occurring by hook and line fishing (Araya et al., 2015, 2018; Godoy et al., 2016). Recreational fishers (divers or anglers) must purchase an annual license, but there are no constraints on individual effort or harvest. Recreational fishing in Chile is defined by law as "activity carried out by natural persons whose purpose is the capture of hydrobiological species with fishing gear for personal use, without profit for the fishers and for the purpose of sport, tourism or entertainment" (Law N° 20.256). In practice, marine recreational fishers in Chile are composed of at least three subgroups; (i) anglers, (ii) spearfishers who extract reef-fish for personal consumption and as a sport, and (iii) spearfishers who sell their catch and operate as commercial fishers with a recreational license. Recently, various stakeholders have raised the need to establish recreational fishery regulations for reef-fish species. Conservation groups and scientists have highlighted the need for management practices to avoid overexploitation. Artisanal fishers have asked for clear rules for the recreational sector to limit reef-fish exploitation by recreational spearfishers with commercial interests. This is relevant considering that in many localities, recreational landings may exceed the biomass removals by small-scale commercial fisheries, highlighting the magnitude and importance of the recreational sector.

In an attempt to begin regulating reef-fish species exploitation, the Chilean Undersecretary of Fisheries and Aquaculture (SUBPESCA for its acronym in Spanish), scientists, and NGOs have brought attention to the need to identify management strategies as a way to kickstart and set an agenda for policy discussions aimed at the management of reef-fish assemblages. Yet, there is little formal information that can be used to assess population status and establish benchmark values. Thus, to fill this gap, this study implemented an expert elicitation protocol to propose specific management measures, such as minimum legal sizes, seasonal closures, and bag limits to regulate recreational reef-fish harvests. These recommendations were used to inform further workshops with recreational sport fishers. This twofold approach enables the establishment of basic information for recreational fisheries regulations in regions where these types of fisheries are growing and in urgent need for regulations. As such, the approach could be of interest to other geographies facing similar issues.

2 | METHODOLOGY

2.1 | Research setting

In Chile, there is a coastal rocky reef-fish fishery that has operated for more than four decades without any regulation or management measures (Araya et al., 2015, 2018; Godoy et al., 2010; Medina et al., 2004). This fishery involves an undetermined number of artisanal fishers and recreational divers and anglers who mostly supply rocky reef-fish to local markets and restaurants. The extracted species that compose the reef-fish assemblage mainly inhabit the rocky sectors of the subtidal between 0 and 30 m depth, associated mainly with *Lessonia trabeculata* kelp forests, with a distribution in Chile from 18°S to 40°S (Nuñez & Vásquez, 1987; Pérez-Matus et al., 2007; Villouta & Santelices, 1984). This group of species is commonly referred to as "rockfish", which includes, but is not restricted to, carnivorous and micro-carnivorous species such as the vieja negra or mulata (*Graus nigra*), pejeperro (*Semicossyphus darwini*), apañado (*Hemilutjanus macrophthalmos*), rollizo (*Pinguipes chilensis*), and bilagay or pintacha (*Chirodactylus variegatus*); omnivores such as the acha (*Medialuna ancietae*) and baunco (*Girella laevifrons*); and the herbivorous jerguilla (*Aplodactylus punctatus*), among other species (Angel & Ojeda, 2001; Araya et al., 2015, 2018; Medina et al., 2004; Palma & Ojeda, 2002).

The recreational fishery essentially involves anglers and divers who use rubber band harpoons as fishing gear, mainly fishing and freediving from the coast (Godoy et al., 2010). Recreational fishers' licenses are awarded on a yearly basis and have increased over the past decade. Anglers, recreational divers, and commercial divers who illegally operate on a recreational license are all included in the registry. By 2021, about 60,000 recreational fishers were registered nationally (Figure 1). Interestingly, between 2020 and 2021, there was an increase of nearly 30% in the number of registered recreational fishers. Although the causes of

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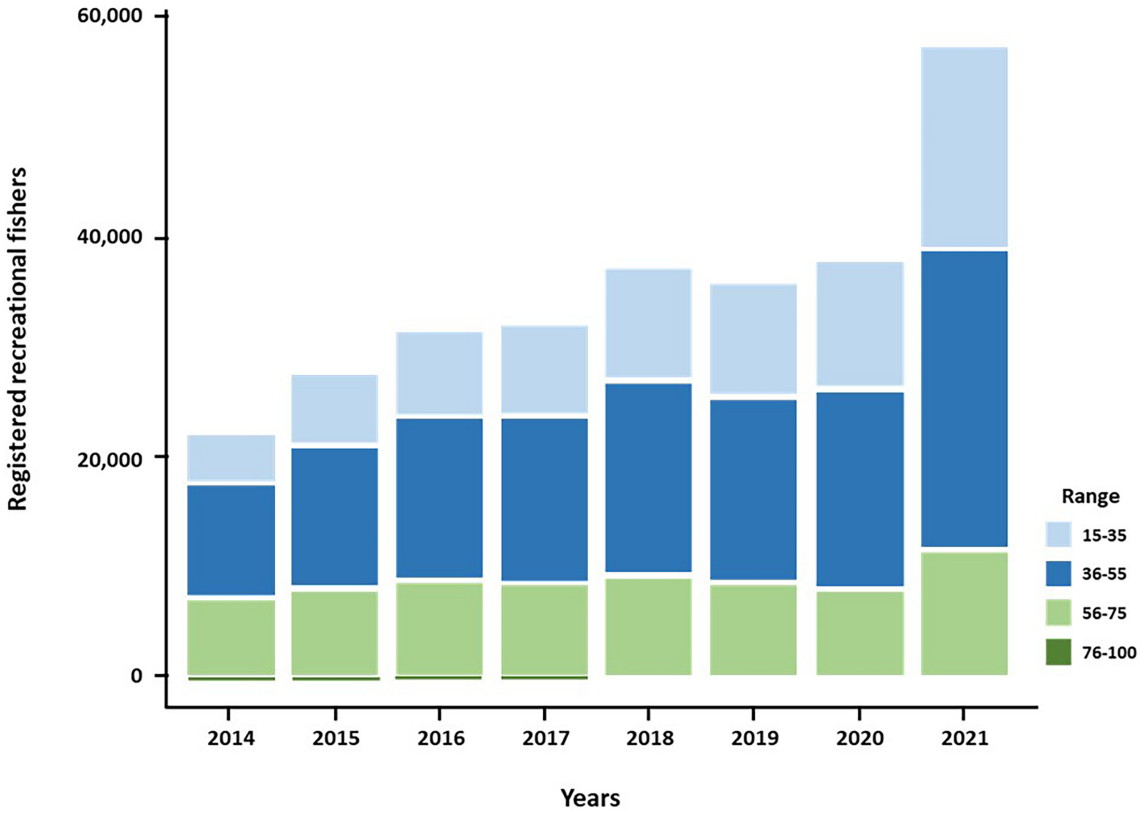

FIGURE 1 Number of registered recreational fishers by age range between 2014 and 2021 in Chile.

this increment are not clear, it is to be expected that this will increase, even further, the extraction pressure on reef-fish. This value may also be underestimated as children under 15 and adults over 65 years old are exempt from obtaining the license. Recreational fishers can be grouped in different fisher associations, which can be found across the country. Associations can organize championships and act as an intermediate level of organization.

2.2 | IDEA protocol

Expert elicitation methods are a useful tool for decision-making in natural resource management when data are insufficient (Sutherland & Burgman, 2015). In these cases, gathering expert judgment in structured and reliable protocols can be a key source of information (Burgman, 2016; Hanea et al., 2021). Unfortunately, unstructured expert elicitation processes are normally applied in environmental management and policy (Estévez et al., 2021; Krueger et al., 2012). In these cases, expert judgments can have serious individual and group biases, including overconfidence, generalization, and anchoring effects, among others (Burgman, 2016; Hemming, Walshe, et al., 2018; Slovic, 1999). Structured expert elicitation methods provide systematic protocols to collect and aggregate judgments from a panel of experts with diverse backgrounds. There are different methodologies to gather and aggregate expert judgment. Some of them focus on building models for planning and decision-making, such as scenario planning, Bayesian networks, and Multi-Criteria Decision Analysis (Hemming et al., 2022). Other approaches focus on estimating uncertain parameters such as Delphi Method and IDEA (Hanea et al., 2016).

The IDEA protocol is a structured and systematic approach to elicit and aggregate expert judgments of uncertain quantities, based on a modified Delphi protocol (Hanea et al., 2017; Hemming, Burgman, et al., 2018). The acronym IDEA emerges from the combination of characteristics of this protocol: Investigate, Discuss, Estimate, and Aggregate expert judgments (Hanea et al., 2016). The IDEA proposes an iterative process, including two rounds of individual estimates, and an open expert discussion phase between estimates (Hanea et al., 2016, 2017, 2021; Hemming, Burgman, et al., 2018; Hemming, Walshe, et al., 2018). First, estimating an uncertain variable, the experts make a first round of individual and independent estimates. These individual estimates are mathematically aggregated to calculate group values (see section 2.3.3). Then, in the discussion phase, experts share arguments that support their first round of estimates, reducing the uncertainty or ambiguity of concepts and problems. After

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TABLE 1 Four-step format elicitation question.

Four-step format
Question: What should be the maximum number of individual pejeperro (*Semicossyphus darwini*) allowed to be harvest per person per fishing trip (bag limit)?
1. Realistically, what is the lowest number of individuals that should be allowed to be harvested per person per fishing trip (bag limit)?
2. Realistically, what is the highest number of individuals that should be allowed to be harvested per person per fishing trip (bag limit)?
3. Realistically, what is your best estimate of individuals that should be allowed to be harvested per person per fishing trip (bag limit)?
4. How confident are you that the true value is between the lowest and highest plausible value? (Between 50% and 100%)

Note: This format can be used for quantity and frequency questions This example was used in the case study presented in this article, based in Hemming, Walshe, et al. (2018). The original questions were presented in Spanish.

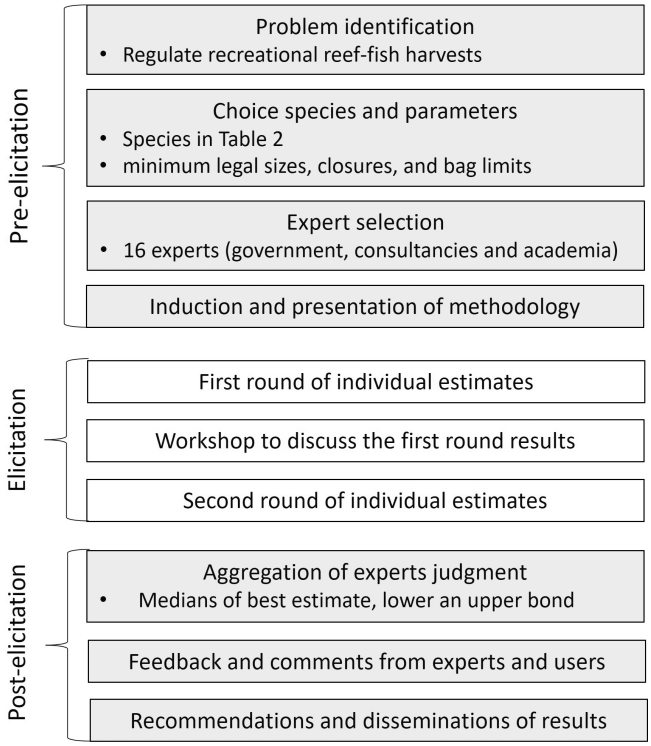

FIGURE 2 Methodological process for the expert elicitation.

the discussion, the experts make a second round of individual estimates, respecting the anonymity of each expert's estimates. Finally, the mathematical aggregation of individual estimates is performed again (see section 2.3.3). Experts are not required to reach a consensus on the estimation (Hemming et al., 2022).

Making estimates for each question in IDEA, experts use a four-step or there-step elicitation format, depending on whether it is a question of quantities or probabilities (Hemming, Burgman, et al., 2018). These formats seek to mitigate experts' overconfidence (Hanea et al., 2016). In the four-step format, which is used to assess quantities, for each estimation, experts indicate an upper and lower plausible bond, their best estimate of the real value (an uncertain number), and a degree of belief that the real value is between the upper and lower bound (how confident you are about the estimations) (Hemming, Burgman, et al., 2018) (Table 1).

2.3 | Elicitation process

There are three main stages in the elicitation process, which correspond to (1) Pre-elicitation, (2) Elicitation, (3) Post-elicitation (Figure 2).

2.3.1 | Stage 1: Pre-elicitation

Problem identification

We defined the problem as an urgent need to generate a proposal of management measures for rocky reef-fish species, considering that most of these species are seriously threatened in their conservation status (Araya et al., 2015, 2018).

Choose species and measures

We chose 17 rocky reef-fish species extracted by artisanal and recreational fishers, based on their fisheries importance (Araya et al., 2015, 2018; Godoy et al., 2016) (Table 1). We selected the management measures commonly used to regulate these fisheries, including a temporal ban (only in the reproductive period), permanent ban, minimum legal size, and maximum number of individuals harvested per person per fishing trip (bag limit) (Arostegui et al., 2021; Haase et al., 2022). For each species, experts estimated minimum legal size and bag limits, and prioritized management measures (see procedures in 2.3.2.3.). Considering species distribution, and the expert's knowledge of recreational fisheries in Chile, experts agreed to divide the area of influence of the 17 rocky reef-fish species into northern (from −18°35′ S to −33°62′ S) and southern zones (from −33°62′ S to −43°40′ S). For each species, experts made independent assessments for the southern and northern zones, except for those species whose range does not include the northern or southern zone, or the status of the species in a zone was unknown to experts (see "not available" in Tables 1 and 2).

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TABLE 2 Second-round estimates for the maximum number of individuals harvested per person per fishing trip (bag limit) (northern and southern zones).

			Northern zone					Southern zone				
ID	Common name	Scientific name	*N*	Median	Min 90%	Max 90%	SD	*N*	Median	Min 90%	Max 90%	SD
1	Pejeperro	*Semicossyphus darwini*	15	1	1.0	1.0	0.56	14	0	0.0	0.0	0.47
2	Vieja negra	*Graus nigra*	15	1	1.0	2.0	0.63	14	1	1.0	1.6	0.85
3	Acha	*Medialuna ancietae*	15	0	0.0	1.0	0.46	Not applicable				
4	Bilagay	*Chirodactylus variegatus*	15	3	2.0	5.1	1.12	13	3	1.9	4.1	0.93
5	Rollizo	*Pinguipes chilensis*	15	4	1.9	5.0	0.83	13	4	2.0	6.1	2.06
6	San Pedro	*Oplegnathus insignis*	15	0	0.0	1.0	0.52	Not applicable				
7	Cabrilla común	*Paralabrax humeralis*	15	3	1.9	4.1	0.70	11	2	1.9	3.1	0.79
8	Vieja tiuque	*Acanthistius pictus*	15	2	0.9	3.1	1.03	13	1	1.0	2.0	0.77
9	Apañado	*Hemilutjanus macrophthalmos*	15	2	1.0	2.1	0.86	Not applicable				
10	Sargo	*Anisotremus scapularis*	15	3	1.9	4.9	0.99	Not applicable				
11	Jerguilla	*Aplodactylus punctatus*	15	4	2.8	6.0	1.03	13	4	2.0	6.0	1.17
12	Blanquillo	*Prolatilus jugularis*	15	4	1.9	5.1	0.80	13	4	1.9	5.1	0.60
13	Róbalo	*Eleginops maclovinus*	Not applicable					12	4	2.5	6.3	1.11
14	Tomoyo	*Labrisomus philippii*	14	3	1.1	4.2	1.14	10	1	1.0	1.5	1.07
15	Cascajo	*Sebastes oculatus*	15	4	2.1	6.4	0.92	13	5	2.8	7.0	1.13
16	Pejesapo	*Sicyases sanguineus*	13	2	1.0	4.1	1.38	Not applicable				
17	Baunco	*Girella laevifrons*	15	4	1.8	6.3	1.19	Not applicable				

Note: *N* = Number of experts who performed the estimation for each species in the second round. Median = The median of the best estimate. Min 90% = The median of the lower bond standardized to 90%. Max 90% = The median of the upper bond standardized to 90%. SD = the standard deviation of the best estimate.

Selection of experts

We utilized two criteria to select experts. First, we sought individuals with recognized experience in rocky reef-fish species management and/or research across Chile. Second, we considered individuals from different sectors, including government services, consultancies, academia, as well as diversity in geographic locations. A total of 20 experts were invited to participate in the study, four declined the invitation. As a result, we selected a group of 16 experts with gained experience in main rocky reef-fish species management and/or research, representing government services (18.5%), consultancies (18.5%), and academia (63.0%). 44% of the participants came from institutions based in Santiago, 19% from institutions based in Iquique, 19% from institutions based in Valparaíso, and the remaining participants came from institutions based in Arica, Coquimbo and Valdivia. Ninety-four percent of the participants were men, which reflects a gender bias associated with the study of reef-fish in Chile.

2.3.2 | Stage 2. Elicitation

First round of individual estimates

First, the project leaders contacted each expert to invite them to participate in the study, explaining motivations, expectations, and context for the expert elicitation process. The project leaders presented the methodology, clarifying doubts about the protocol. A week later, the project leaders sent an email to the experts containing the questions for 17 species in an Excel file (see Table 1 for an example of the type of questions). We encouraged experts to use their experience and available scientific knowledge. If an expert did not have direct experience or knowledge in some species, we suggested to omit those questions. Therefore, not all the experts made estimates for all species in both rounds.

Workshop to discuss the first round of individual estimates

First-round results were aggregated, generating graphs and measures of central tendency (median and mean) for

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each species. Subsequently, the experts participated in a workshop, facilitated by the first author of this article. In this workshop, the experts reviewed and discussed the results of the first round of individual estimates. For each species, the facilitator stimulated discussion especially on those questions with greater inter-expert dispersion. The experts presented arguments and scientific research results to support their estimates.

In the workshop, the experts were also asked to prioritize management measures for each of the species. Four management measures were identified: permanent ban, temporary ban, bag limit, and minimum legal size. For each species, the experts had the option of selecting one or more management alternatives. Then, we calculated the percentage of experts that selected each management alternative for each species.

Second round of individual estimates

During the workshop, the experts conducted the second round of individual estimates. After discussion and review of the results of the first round for each species, the experts were asked to perform the second round of individual estimates. In this second round, anonymity and independence were maintained in each of the estimates. The second-round estimates were considered as the final estimates, adjusted by each expert according to the arguments presented in the group discussion phase. Therefore, the results of the second round are presented in the results (the results of the first round are included as supplementary material: Data S1).

2.3.3 | Stage 3. Post-Elicitation

Aggregate experts' judgments

To estimate uncertain quantitative variables, most applications of the IDEA protocol calculate the median of lower, upper, and best experts' estimates (Hemming, Walshe, et al., 2018). We used equally weighted group aggregations. That is, all experts had the same relative weight independent of potential outlier estimates, which were included into discussion (Hemming, Burgman, et al., 2018). The standard deviation was used as a measure of the interexpert variation of the individual estimates (Adams-Hosking et al., 2016). The upper and lower bond of each participant estimates were standardized to 90% using linear extrapolation (Hemming et al. 2018,b). This permits the experts to compare their intervals on the same scale for all questions.

Feedback and comments

The results of the second round of estimations were sent to the participating experts via e-mail. Feedback was also received via video conference. The experts did not request any modifications or adjustments to the estimates, agreeing with the results obtained. Later, the project leaders facilitated a workshop of recreational fishers to discuss the estimates made by the experts. In this workshop, seven representatives of the Chilean Hunting and Fishing Federation (FECAPECH-FDN for its acronym in Spanish) and the National Sports Federation of Underwater Activities and Aquatic Rescue (FEDESUB for its acronym in Spanish) participated. Both organizations represent several sport and recreational fishing associations. The goal of the user workshops was to present results and receive feedback. In this workshop, we reviewed the results for each species, discussing mean values and outliers with recreational fishers. We also analyzed together the arguments supporting the experts' estimates, as well as potential inconsistencies. This workshop did not attempt to modify the results of the expert workshop, but rather to discuss possible discrepancies and validate these results with recreational fishers.

3 | RESULTS

Expert elicitation results show that for the 17 species evaluated, the maximum number of individuals harvested per person per fishing trip recommended was between 0 and 5 (Table 2). For the acha, San Pedro, and pejeperro species (in the southern zone), the median of the maximum number of individuals harvested was zero, which is equivalent to a permanent ban. Five species had a median equal to 1. The medians of the best estimate were similar between the northern and southern zones, with maximum differences of 1 individual. To illustrate the results of the workshop, Figure 3 shows the results for two species after the second round of estimations.

As expected in the IDEA protocol, the experts adjusted their estimates between the first and second rounds (see supplementary material: Data S1). Of the 25 best estimates made to establish the bag limit (for several species the estimates were made for the northern and southern zone), only 10 medians of the best estimate remained the same between the two rounds. In the other 15 cases, the medians of the best estimate were reduced to a more precatory value. Likewise, as expected between the two rounds, the variance of the best estimate was systematically reduced in 92% of the cases, reducing the interexpert dispersion. For example, for the bilagay, in the first round the median best estimate was 4, with a standard deviation of 2.50. In the second round, the median best estimate was 3, with a standard deviation of 1.12.

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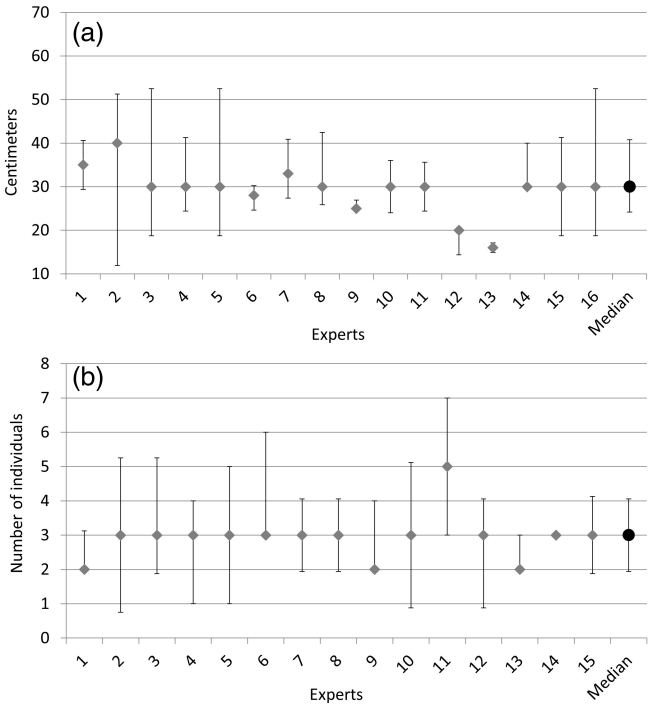

FIGURE 3 Example of the figures presented at workshops. (a) Minimum legal size for baunco at northern zone. (b) Maximum number of individuals harvested per person per fishing trip for cabrilla común at northern zone. The gray dots represent each expert's best estimate. The black dot represents the median of the best estimates. The lines represent the upper and lower bond standardized to 90%. For the black dot, the lines represent the median of the upper and lower bonds standardized to 90%.

For the 17 species evaluated, the minimum legal size recommended was between 20 and 50 cm (Table 3). These differences are expected due to variations in the size at maturity for each species. For smaller species, such as tomoyo, cascajo, and pejesapo, the minimum legal sizes recommended were 28, 20, and 20 cm, respectively. On the other hand, for larger species, such as the pejeperro (male), vieja negra, and acha, the minimum legal sizes recommended were 50, 50, and 45 cm, respectively. The medians of the best estimate were similar between the northern and southern zones. The largest differences were in the vieja negra (6.5 cm larger in the southern zone) and male pejeperro (4.4 cm larger in the southern zone). Like the establishment of the bag limit, in the calculation of the minimum size, the experts made modifications to their estimates between the two rounds. And as expected, the variance of the best estimate was systematically reduced between the two rounds in the 80% of the cases. For example, for rollizo in the southern zone, in the first round, the median of the best estimate was 36 cm, with a standard deviation of 10.08. In the second round, the median of the best estimate was 30 cm, with a standard deviation of 5.20.

On average for the 17 species, the most recommended measures were bag limits (59.6%) and temporal bans (reproductive period) (57.0%). Minimum legal size (27.6%) and permanent bans (21.1%) were, on average, recommended less. However, the recommended management measures vary significantly among species (Table 4). For example, for acha, permanent ban was indicated by 100.0% of respondents, while the use of bag limits and minimum legal size was not selected (0%). On the other hand, for blanquillo, bag limit was indicated by 87.5% of respondents, while minimum legal size and temporary were indicated by 37.5% and 25.0%, respectively, signaling toward multiple management measures.

Finally, in the workshop of recreational fishers, the results were reviewed species by species. The participants agreed to establish heterogeneous measures for each species. In particular, representatives of the hand line fishing organizations agreed with the establishment of catch limits per fishing event, considering that catch-and-release protocols are used in their competitions. In the workshop, participants stressed important topics, such as the difficulty to distinguish and increasing conflicts between recreational and artisanal-commercial fishing when divers are spearfishing. Participants also recognized and supported the establishment of severe measures, such as a permanent ban for clearly overexploited species (e.g., acha and San Pedro). However, they highlighted the need to previously socialize these results within their organizations. An aspect discussed by participants of the workshop was the need to provide support for recreational fisher associations who can promote and are interested in complying with catch regulations.

4 | DISCUSSION

In Chile, reef-fish fisheries have been deemed overfished, but no commercial or recreational regulations regarding bans, capture limits, gear restrictions, or size limits exist. The SUBPESCA, scientists, and NGOs recognized the need to set an agenda for policy and management discussions to control reed-fish extractions. In this study, we designed and conducted an expert elicitation process, based on the IDEA protocol, to evaluate management strategies for 17 rocky reef-fish species extracted by artisanal and recreational fishers. Experts recommended minimum legal sizes and maximum number of individuals harvested per person per fishing trip for each species. They also evaluated the most appropriate management measures, considering permanent and temporal bans, minimum legal size, and bag limits. The results show a high degree of heterogeneity, where the maximum number of individuals harvested per person per fishing trip vary between 1 and 7 individuals

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TABLE 3 Second-round estimates for the minimum legal size of reef-fish caught by recreational fishing (northern and southern zones).

			Northern zone					Southern zone				
ID	**Common name**	**Scientific name**	**N**	**Median**	**Min 90%**	**Max 90%**	**SD**	**N**	**Median**	**Min 90%**	**Max 90%**	**SD**
1	Pejeperro female	*Semicossyphus darwini*	15	30	28.1	40.0	9.86	14	30	28.1	39.7	10.08
1	Pejeperro male	*Semicossyphus darwini*	14	45	38.6	50.3	10.19	14	45	33.9	50.3	7.23
2	Vieja negra	*Graus nigra*	15	50	38.8	55.0	10.86	13	50	38.8	55.3	12.92
3	Acha	*Medialuna ancietae*	13	45	39.4	55.0	8.03					
4	Bilagay	*Chirodactylus variegatus*	15	30	24.4	31.3	4.82	12	30	24.7	34.7	3.87
5	Rollizo	*Pinguipes chilensis*	15	30	25.0	36.0	4.44	13	35	25.0	36.2	5.20
6	San Pedro	*Oplegnathus insignis*	11	31	26.6	35.6	4.73	Not applicable				
7	Cabrilla común	*Paralabrax humeralis*	15	30	22.4	35.0	6.17	11	30	24.7	35.0	4.76
8	Vieja tiuque	*Acanthistius pictus*	15	35	28.6	40.6	5.46	12	35	28.0	40.6	5.59
9	Apañado	*Hemilutjanus macrophthalmos*	15	40	29.9	45.6	6.28	Not applicable				
10	Sargo	*Anisotremus scapularis*	15	30	24.6	35.3	3.84	Not applicable				
11	Jerguilla	*Aplodactylus punctatus*	15	35	29.7	40.6	2.56	13	35	29.7	42.4	3.15
12	Blanquillo	*Prolatilus jugularis*	15	25	21.1	30.6	4.83	13	25	21.1	30.6	4.72
13	Róbalo	*Eleginops maclovinus*	Not applicable					11	35	29.4	40.3	6.96
14	Tomoyo	*Labrisomus philippii*	15	28	22.8	30.6	4.17	11	30	20.0	33.8	4.78
15	Cascajo	*Sebastes oculatus*	14	25	19.5	29.2	3.03	13	24	19.4	28.3	3.12
16	Pejesapo	*Sicyases sanguineus*	12	21	14.5	27.2	4.36	Not applicable				
17	Baunco	*Girella laevifrons*	16	30	24.2	40.8	5.47	Not applicable				

Note: *N* = Number of experts who performed the estimation for each species in the second round. Median = The median of the best estimate. Min 90% = The median of the lower bond standardized to 90%. Max 90% = The median of the upper bond standardized to 90%. SD = the standard deviation of the best estimate.

according to each species. On the other hand, bans are recommended for some species, such as acha, pejeperro, and San Pedro, which are evidently overexploited, but would not be recommended for other species such as rollizo or jerguilla, which require bag limits or minimum legal size.

Results of this study show the utility of expert knowledge to propose management measures in recreational reef-fish fisheries. The IDEA protocol proposes an iterative process, in which individual estimates are linked to a group discussion phase (Hemming, Burgman, et al., 2018; Hemming, Walshe, et al., 2018). The first round of estimates was based on an independent reflection of each expert. Subsequently, the discussion phase played a key role in adjusting the individual estimates (second round), based on the knowledge shared in a space led by a facilitator (supplementary material: Data S1). In this case study, a systematic adjustment of the estimates in the second round was observed with respect to the first round. As indicated in the results, more than 90% of the estimates were adjusted in the second round. Additionally, in the second round, a greater agreement in the results was achieved, expressed in a systematic decrease in the interexpert dispersion.

Our results are consistent with other studies, which highlight the importance of stakeholder and expert knowledge for recreational fisheries research (Bower et al., 2017, 2020; Diogo et al., 2017). Recreational fisheries generally operate under de facto open access regimes, with no limits on fishing effort (Arlinghaus et al., 2019). As a result, several recreational fisheries are in a state of overexploitation (Cooke & Cowx, 2004; Hyder et al., 2017). Therefore, there is national and international consensus on the need to advance in the establishment of management measures to avoid the collapse of reef-fish resources (Holder et al., 2020). Bag limits are a common management measure in recreational fisheries, restricting the number (or weight) of fish that may be harvested (Arostegui et al., 2021). International experiences show that the establishment of bag limits can reduce removals in recreational fisheries (Haase et al., 2022; Lennox et al., 2016), although different groups of recreational anglers may respond differently to changes in the bag limit (Beard Jr et al., 2003; Beardmore et al., 2011). For example, establishing bag limits on the number of fish normally taken by recreational fishers may affect only the most successful fishers, resulting in a smaller

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TABLE 4 Percentage of experts that selected each management alternative for each species.

ID	Common name	Temporal ban (%)	Permanent ban (%)	Bag limit (%)	Minimum legal size (%)
1	Pejeperro	31.3	81.3	37.5	18.8
2	Veja negra	94.4	16.7	44.4	44.4
3	Acha	27.8	100.0	0.0	0.0
4	Bilagay	88.9	0.0	66.7	27.8
5	Rollizo	33.3	0.0	77.8	72.2
6	San Pedro	5.6	94.4	16.7	16.7
7	Cabrilla española	64.7	0.0	82.4	35.3
8	Vieja tiuque	75.0	25.0	43.8	18.8
9	Apañao	100.0	0.0	55.6	27.8
10	Sargo	53.3	0.0	73.3	26.7
11	Jerguilla	29.4	0.0	76.5	47.1
12	Blanquillo	25.0	0.0	87.5	37.5
13	Robalo	43.8	0.0	81.3	25.0
14	Tomoyo	87.5	12.5	62.5	18.8
15	Cascajo	76.5	5.9	70.6	17.6
16	Pejesapo	83.3	16.7	55.6	16.7
17	Baunco	50.0	6.3	81.3	18.8

Note: Experts could select more than one alternative.

reduction in stock mortality (Askey & Johnston, 2013; Woodward & Griffin, 2003). On the other hand, minimum legal size can have a positive impact on populations by ensuring that individuals reach sexual maturity before being harvested, increased spawning potential ratio and population resilience (Arostegui et al., 2021; Coggins Jr et al., 2007; Post et al., 2003). However, the establishment of minimum legal sizes could promote the extraction of larger individuals, which have a greater reproductive capacity (García-Asorey et al., 2011; Matsumura et al., 2011). While this background information is important to evaluate the relevance of management measures, the experts in this study agree on the need to move towards the implementation of bag limits, minimum legal size, and temporal and permanent bans, considering the differences between species that determine the relevance of each measure.

Recreational fishery management measures should create incentives for compliance by recreational fishers (Arlinghaus et al., 2019; Haase et al., 2022). In Chile, recreational fishers purchase an annual license that currently contains no restrictions on extraction efforts. Therefore, individual recreational fishers have no incentive or benefit to limit their fishing effort (e.g., a perception that self-regulation will improve sustainability of fisheries). In addition, recreational fishers are highly heterogeneous, and their motivation for fishing may be relaxation, enjoying nature, or generating income through the commercialization of their catches (Arlinghaus et al., 2017; Johnston et al., 2010). Therefore, the establishment of management measures should consider not only biological outcomes but also social acceptability and potential compliance (Brownscombe et al., 2019; Hunt et al., 2013; Johnston et al., 2010). However, it is difficult to predict fishers' responses to management measures (Arlinghaus et al., 2013, 2017; Beard Jr et al., 2003; Beardmore et al., 2011; Holder et al., 2020; Hyder et al., 2020). Future studies in Chile should address social acceptability and drivers for recreational fishers' uptake of the selected management suggestions.

Despite the lack of information on Chilean recreational fishers' preference, internationally, several studies show that size restrictions, such as minimum legal size, are one of the management measures best accepted by recreational fishers (Arostegui et al., 2021). This measure imposes fewer restrictions, both in terms of fishing times and the number of individuals that can be extracted (Dawson & Wilkins, 1981; Murphy Jr. et al., 2015; Quinn, 1992). On the other hand, establishing restrictions on the maximum number of individuals harvested per person per fishing trip tend to be a less preferred option for recreational fishers (Cardona & Morales-Nin, 2013; Dawson & Wilkins, 1981; Murphy Jr. et al., 2015). Limitations on extraction quantities reduce the

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value of a potential day's catch (Lew & Larson, 2015; Swallow, 1994). Although, recreational fishers who target large fish over the ability to catch higher numbers may have positive perceptions about bag limits (Aas et al., 2000; Arostegui et al., 2021; Hutt & Bettoli, 2007). Fishing bans are generally the least accepted measures by recreational fishers (Abbott et al., 2018; Dorow et al., 2009; Hutt & Bettoli, 2007). In the Chilean case, there is no conclusive evidence regarding the preferences of recreational fishers. This is a limitation of the study, which requires the implementation of attitudes and preferences regarding management measures. In the workshop held with recreational fishers to evaluate the results of the study, it was possible to advance this knowledge and thus propose working hypotheses. Recreational fishers report an evident decline in the populations of some emblematic species for recreational fishing, such as acha, pejeperro, and vieja negra. Therefore, there was a broad willingness on the part of fishers to support stricter management measures. Including the reduction of the limit of individuals per fishing event. However, fishers expressed concern about the ability to ensure compliance with these measures, considering the systematic increase in the number of registered recreational fishers (Figure 1).

A central issue that arises for recreational fisheries in the workshop was the increasing conflicts between stakeholders due to the lack of clarity between recreational and commercial licenses. Internationally, conflicts may emerge due to the impact of recreational fisheries on fish stocks (Abbott et al., 2018; Coleman et al., 2004; Freire et al., 2020; Radford et al., 2018), competition between commercial and recreational fishers for the catch of a single species (Freire et al., 2016, 2017; Kadagi et al., 2020; Lyman, 2008), inadequate discarding of fishing equipment and habitat disturbance (Lynch et al., 2004; O'Toole et al., 2009; Yorio et al., 2014), or even conflicts among recreational fishers due to the practice of catch-and-release (Aas et al., 2002; Arlinghaus et al., 2007; Policansky, 2002). In Chile, there are spearfishers that extract rocky reef-fish for sport and personal consumption, and spearfishers that extract for commercialization to restaurants and local markets (Godoy et al., 2016). Although there is evidence of conflicts between licensed recreational fishers and artisanal fishers in Chile, there are no studies describing the dynamics and estimating the magnitude of these emerging conflicts. We suggest future studies should pay attention to this issue.

Information gathered through expert elicitation is key to inform other data poor fishery management approaches. For instance, information on main management measures and limits for these 17 species is currently being used to inform a decision support tool for fisheries management with limited data, called FishPath, which is being led by the NGO, The Nature Conservancy (Crosman et al., 2020; Dowling et al., 2016). Ideally, the integration of formal expert elicitation processes with this type of participatory decision support tool, aimed at creating ownership and maximizing stakeholder buy-in, can provide important synergies to begin managing recreational fisheries in developing and mid-income countries.

Despite the paucity of information on recreational fisheries globally, and the heterogeneity of recreational data quantity and quality between countries, these fisheries significantly impact coastal marine resources and ecosystems. Accordingly, governments must advance in recreational fishery regulation, even in the face of limited data. Here, we have shown how expert elicitation techniques can provide a systematic way to advance in informing these types of policies. The methodology applied allowed for structured consideration of species-specific potential management measures for 17 rocky reef-fish in Chile. Results included a suite of proposed measures, such as the maximum number of individuals harvested per person per fishing trip, minimum legal sizes, and temporal bans, but it is also necessary to advance in the consideration of other measures such as quotas or restrictions for access to recreational fishing licenses. Recommended next steps involve continuing to socialize the proposed management measures to promote acceptability and compliance, while pursuing a policy framework that incorporate these recommendations into recreational fisheries governance at regional and national levels. The approach presented here is important to initiate much needed discussions for the sustainability of data-poor recreational reef-fish fisheries in Chile and beyond.

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DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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